PG&E's Compressed Air Energy Storage (CAES) Project

EESAT 2015 Technical Conference / DOE ESSP Peer Review

Portland, OR

Pacific Gas and Electric Company

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Project Overview

300 MW, up to 10 hours storage*, in a porous rock reservoir in CA

Three phases:

1. Reservoir testing, plant design (currently funded)
2. Permitting, interconnection, bid and plant construction
3. Operations, Data Collection & Technology Transfer

Project Objectives

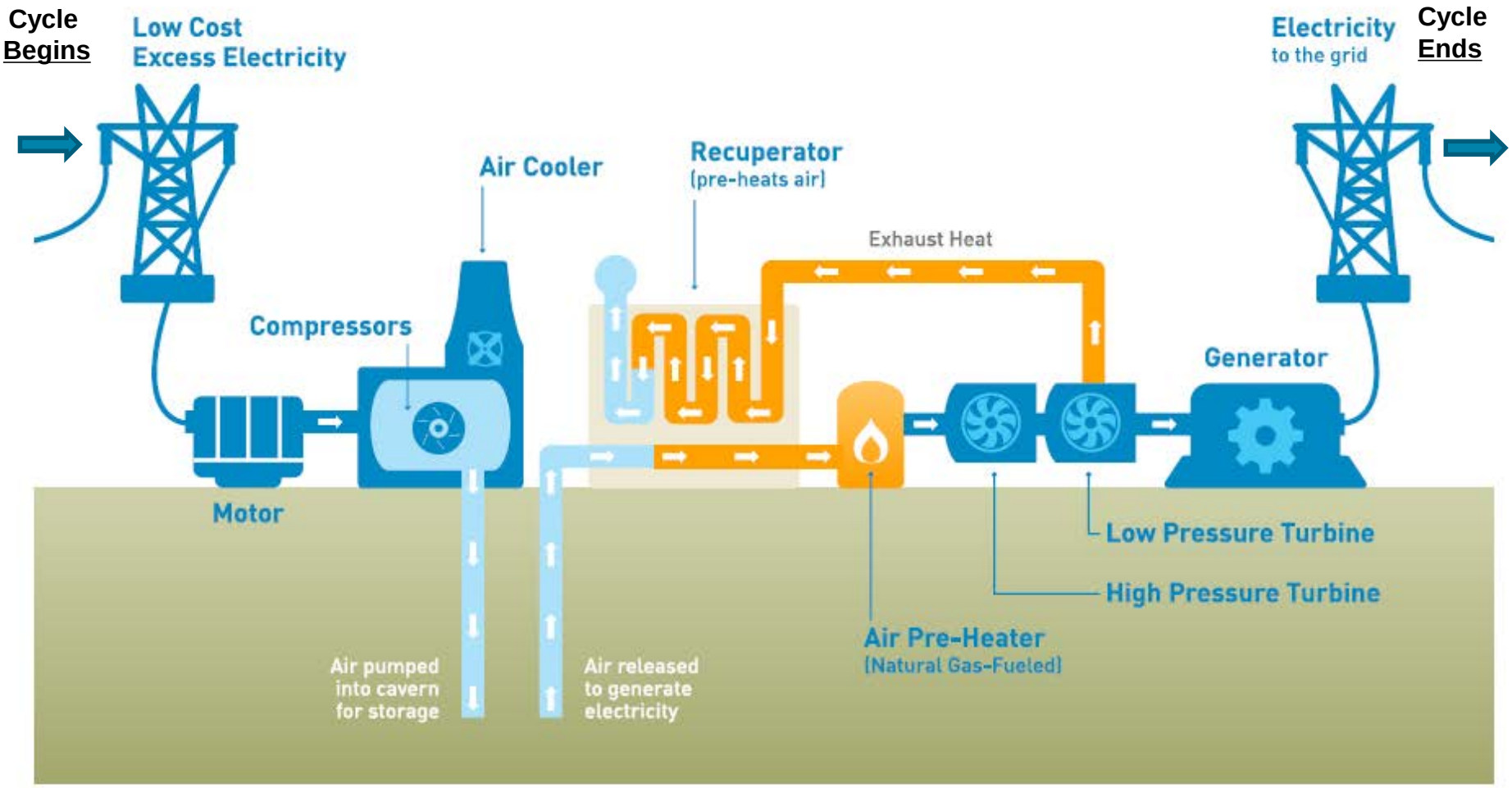
- Verify the technical performance of advanced CAES technology using a porous rock formation as the underground storage reservoir
- Integrate intermittent renewable resources
- Maintain emergency spinning/non-spinning reserve and perform volt-ampere reactive/voltage support

Phase 1 Funding:

PG&E Customers

* Final Project size will be determined by reservoir size / definition and by testing results, subject to management & CPUC approvals.

CAES Cycle



Achievements – Site Selection/Permitting

- Long term site control agreements in place
- Received core drilling permits
- Top site was selected for Air Injection Test (AIT) based on detailed diligence and environmental screening
- Environmental Assessment and FONSI issued by DOE for AIT

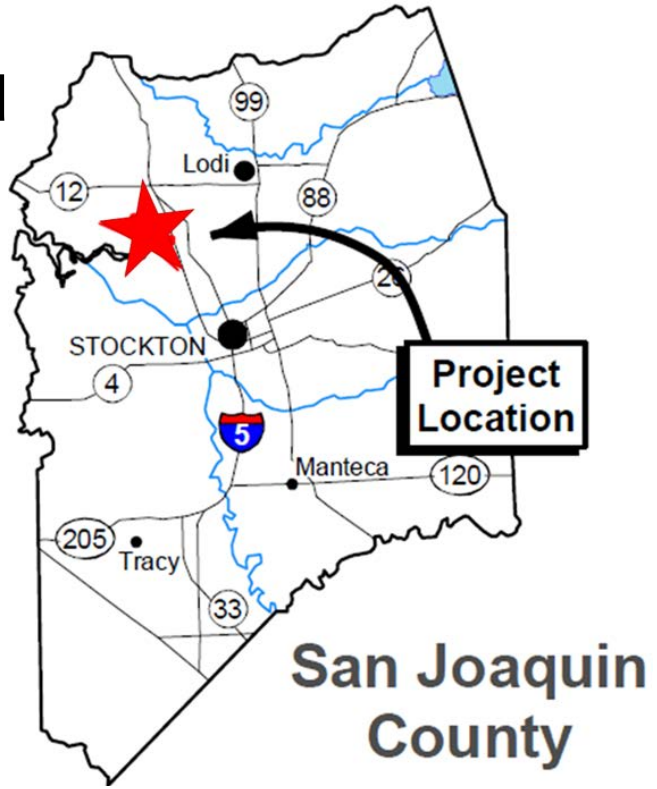
  (http://www.netl.doe.gov/File%20Library/Library/Environmental%20Assessments/5-15-14-signed-PGE-FONSI.pdf)
- EPA UIC (Underground Injection Control) permit issued for AIT

  (http://www.epa.gov/region09/water/groundwater/uic-permits.html)
- Environmental Siting Licensing and Permitting Analysis (ESLPA) report

Lessons Learned- Site Selection/Permitting

- **Geology drives key performance and development indicators**

- **Key drivers:**
  - Field size and depth (pressure)
  - Geologic properties (core results, production data, etc.)
  - Field is depleted or nearly depleted with minimal number of wells
  - Possible ECF site in close proximity
  - Infrastructure (proximity to gas, power, water, etc.)
  - Environmental and/or public policy
    - CEC permitting feasible under AFC process
    - EPA permitting feasible under UIC process



Achievements – Engineering

- Selected top 2 sites from over 100 reservoirs considered
- Completed core well contracting, drilling and demobilization (2 sites) with excellent permeability and porosity results
  - 300 feet of core extracted
  - Excellent permeability measuring up to 3,000 mD and porosity of 25-32%
  - Data used in dynamic computer model
- Completed preliminary engineering analysis of surface and subsurface technologies
- Established feasibility of bifurcating Energy Conversion Facility (ECF) and reservoir/well pads
- Reservoir model constructed utilizing 3D seismic data
- Reservoir model tuning & full field development design

Lessons Learned - Engineering

- Surface Plant technology: Next Generation of DR Alabama technology “SmartCAES”
  - HP and LP Fired Turbo-expanders with HHP stage
  - Use of recuperator (air-air heat exchanger) for heat recovery
  - Quick start capability (10 min to full load)
  - Low turndown ratio (Pmin) with minimal heat rate impact at low loads
  - Quick ramp rate (up and down)

- Subsurface Technology
  - Depleted natural gas reservoir >> 20-30 I/W wells
  - Likely water production/removal (various disposal alts)
  - Bifurcated reservoir/storage and ECF
  - Reservoir model updated, validated and used to project full development operations

Air Injection Test (AIT) – Facility

- I/W test well completed in the storage reservoir
- 7.5 MW temporary compression plant

Air Injection Test – Results

- Test Conditions
  - Injection/withdrawal designed to mimic full field operation
  - Built bubble at 1/16 scale (500 MMscf)
  - Injected depleted O2 air for initial test
  - Based on successful results of initial test, conducted testing with ambient air
- Key parameters monitored
  - Residual hydrocarbons in withdrawal stream
  - Water production
  - O2 depletion within the reservoir
- Results used to update and validate model
  - Update the reservoir model and then extrapolated to determine expected performance and operations of a full field development
  - Development cost model updated for use by future developers and/or lenders
- Deliverability and residual hydrocarbons
  - I/W well deliverability can support full scale development
  - Residual hydrocarbons in withdrawal stream less than modeled

Major Milestones

Phase 1 (Feasibility / Testing)	Projected Completion
Select Viable Sites Based on Desktop Analysis	Completed
Site control for top 2 sites	Completed
Complete Core Drilling & Analysis for 2 Sites	Completed
Select Air Injection Site	Completed
Conduct RFPs for Injection Test Contractors	Completed
Obtain NEPA & EPA Permit / Approvals for Air Injection Testing	Completed
Begin Injection Test	Completed
Injection Testing Complete	Completed
NEXT	
Issue RFO for Plant Ownership, Construction & Operation	October, 2015
RFO Responses Due	May, 2016
Complete RFO Process	November, 2016
Go/No-Go Decision	December, 2016

Next Steps

- Process all AIT results, including reservoir model tuning
- Consolidate all project artifacts in data room format
- Prepare and conduct an RFO
- Evaluate results of RFO; if bids are economic and need determined, negotiate terms and select successful candidate(s)
- If negotiations are successful, seek CPUC approval

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